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LOCKING DEVICE WITH
SOLENOID RELEASE PIN

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LOCKING DEVICE WITH SOLENOID RELEASE PIN

BACKGROUND OF THE INVENTION

The present invention relates to a locking device. In various environments, especially for flight vehicles and projectiles, it is necessary to quickly and reliably release structural members for deployment yet securely hold such members in a retracted position for storage, transportation, or other pre-deployment requirements.

In certain applications such as smart bombs with movable fins (for guidance), missiles with movable fins, and satellite or space vehicles and equipment with deployable panels (e.g., solar panels), it is desirable to provide a large margin of safety in design. For such situations, the fins or panels are biased towards their deployment position with a large force, often a spring force. This force must be securely and reliably held in place prior to deployment. Premature deployment could easily damage the fins or panels, or cause other problems. Failure to deploy could result in an errant bomb or missile, or a satellite's premature loss of power.

In one proposed smart bomb design, a pin supported by plastic holds a first spring-biased member in place, which through mechanical linkage holds torsion springs in place. Mechanical linkage helps reduce the force to about 200 to 300 pounds needed to hold the spring-biased member in the locked position. When the pin is released, the torsion springs will cause the fins to be unlocked and thus deployed. To obtain a quick release, a predetermined amount of explosive is ignited to break the plastic, thereby, releasing the pin.

2 Another system to release a locking element or pin as used in airborne vehicles
and projectiles includes cutting a bolt, which holds two elements relative to each other, so
4 as to release satellite photovoltaic panels and antenna reflectors. A further system
involves weakening a nut, e.g., by cutting a portion of the nut, then exploding the nut at
6 the time of deployment. These systems all involve destruction, and are thus cumbersome
and expensive to handle, test and replace.

8 In U.S. Patent No. 6,224,013 to Chisolm, a tail fin deployment device uses lock
balls to hold a cup member that in turn through linkage holds tail fins in a retracted
10 position. A pin having recesses is spring-biased so that the recesses are in alignment with
the apertures holding balls, but the pin is held by a lanyard in a position where its
12 recesses are out of alignment with the balls. The lanyard is tied to the aircraft, so when
the bomb is released, the lanyard comes out. Even in this design, the lanyard has to be
14 pulled so as to overcome about 300 pounds of force from a spring. Moreover, this design
necessitates hooking the lanyard to the aircraft.

16 Locking balls and the like have been used in various devices, such as manual
positive lock pins, e.g., made by Pivot Point, Inc. of Hustisford, Wisconsin. Pressing
18 down on a button pushes a pin so as to align a recess in the pin with locking balls. When
aligned, the balls enter the recess and release a locked member.

20 U.S. Patent No. 6,074,140 to Cook secures a drill bit in place with a lock ball
chuck. It is stated that a mechanical, solenoid or manual chuck may be used although no
22 actual structure is shown.

U.S. Patent No. 4,523,731 to Buitekant et al. uses a manual pull pin to release a
24 plunger in turn releasing lock balls. The lock balls hold a flight vehicle to an external

2 storage element. This manual release is disclosed as an alternative to the explosive
severing of a bolt that held the flight vehicle and storage element together in a prior
4 design.

U.S. Patent No. 5,216,909 to Armoogam discloses an electro-mechanical locking
6 mechanism for selective operation of a latch. A solenoid is used to push a pin down
which pushes down a bolt locking pin, enabling movement of a piston transverse to the
8 bolt locking pin.

Other patents using various locking mechanisms include U.S. Patent Nos.
10 3,985,213 to Braggins, 5,628,216 to Qureshi et al., 4,289,039 to Trunner et al., 5,600,977
to Piron, and 4,565,183 to Smith.

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SUMMARY OF THE INVENTION

14 In one embodiment, there is a locking device with a solenoid to actuate release of
the lock. The locking device includes a housing with a solenoid and a metal or
16 magnetically responsive element disposed proximate or within a coil or coils of the
solenoid. The responsive element (such as a plunger) is spring biased into its locked
18 position. In such position, a lower portion of the responsive element (plunger) holds one
or more balls, for example ball bearings, in a position where they protrude from the
20 housing. In turn, the ball or balls hold a further element in a locked position. The portion
of the magnetically responsive element (e.g., the bottom of the plunger) holding the balls
22 has a recess or recesses proximate but not in alignment with the ball or balls when in the
locked position.

24 Actuating the solenoid by sending current through the coils moves the plunger, by

2 an induced magnetic field, against the bias of the spring to a release position. In the
release position, the recess or recesses of the bottom portion of the plunger receive the
4 ball or balls. The balls no longer protrude from the housing, and thereby release the lock
on the element being held. This locked or held element may also be biased, e.g., spring
6 biased to move when the lock balls are released. The locked element when released may
activate, directly or in conjunction with various linkage or components, the deployment
8 of fins, such as fins for a smart bomb, missile, or torpedo. The released member may
also activate or deploy solar panels for a satellite, or other member, especially for
10 airborne use, but may include other uses as well.

In other embodiments, the device may use a lever in place of a ball or balls, it
12 may use staged or staggered releases, and/or it may release multiple balls at once.

14 **BRIEF DESCRIPTION OF THE DRAWINGS**

16 Figure 1 is a partial sectional view of a locking device in a locked position in
accordance with a first embodiment of the invention;

18 Figure 2 is a view similar to Figure 1 but in a released position;

Figure 3 is a view similar to a portion of Figure 1 and showing a second
20 embodiment of the invention using a lever valve in a locked position;

Figure 4 is a view similar to Figure 3 but in a released position;

22 Figure 5 is a view similar to Figure 1 of a third embodiment of the invention using
a staggered release and in a locked position;

24 Figure 6 is a view similar to Figure 5 but in a first released position;

2 Figure 7 is a view similar to Figure 5 but in a second fully released position;

 Figure 8 is a view similar to Figure 5 but of a fourth embodiment in a locked
4 position;

 Figure 9 is a view similar to Figure 8 but in a released position;

6 Figure 10 is a partial schematic partial perspective view of a missile or smart
bomb with its fins locked in a retracted position;

8 Figure 11 is a view similar to Figure 10, but with the fins released and thereby
deployed;

10 Figure 12 is an enlarged sectional partial cutaway view of a locking device in a
locked position in accordance with a fifth embodiment of the invention; and

12 Figure 13 is a view similar to Figure 12, but in a released position.

14 **DESCRIPTION OF THE PREFERRED EMBODIMENT(S)**

16 A locking device with a solenoid-actuated release pin in accordance with a first
embodiment of the invention is shown in Figure 1. The device has a housing 2, which
18 may be a nonconductive material such as plastic, or may be conductive. The device also
has a metal or otherwise magnetically responsive plunger or pin 4 axially slidable with
20 respect to the housing, a magnetic coil 6 fixed to the housing 2 (e.g., by bolting), two
locking balls 8, a biasing member 10, for example a compression spring, to bias plunger 4
22 in a first direction, and a power on circuit 12, typically including a battery or other
electrical power source, a switch or circuit to turn on the power, and a capacitor and/or a
24 resistor connected to the coil 6, e.g., by wires 6a, 6b.

2 Plunger 4 has a surface 4a against which biasing member 10 presses. Plunger 4
also has a shaft 4b with a recess or groove 4c, preferably with chamfered or beveled
4 edges 4d. Shaft 4b is slidably fit within a cylindrical chamber 14 defined by a lower
portion 2a of housing 2. Lower portion 2a of housing 2 has two chamfered or beveled
6 apertures 2b defined therein where balls 8 are disposed.

When plunger 4 is in its locking position (the up position in Figure 1), upper
8 surface 4e of plunger 4 presses against the inside surface 2d at the top of housing 2, and a
non-recessed portion of shaft 4b is adjacent balls 8 holding them in a radially outward
10 position (locking position) as shown in Figure 1. In this position, an element 20 is held in
a locked or storage position, thus being prevented from moving. Accordingly, element
12 20 may be held in place against external forces such as inertial and surface or contact
forces (downward in Figure 1) acting on it. Such external forces may include, for
14 example, those exerted by gravity, an airstream, water or other biasing device such as a
spring, one or more magnets, or the like. Typically, in airborne devices and projectiles,
16 the external forces that are present may be quite high. To counter such external forces for
airborne devices and projectiles in certain embodiments, the biasing force of spring 10 on
18 plunger 4 may be about 150 pounds to about 200 pounds, e.g., 185 pounds or even higher
than 200 pounds.

20 In a preferred embodiment, element 20 has a recess or aperture formed therein to
provide space to locate the lower portion 2a of housing 2, the shaft 4b of plunger 4, and
22 the locking balls 8. Together biasing member 10, solenoid 6, locking balls 8 and plunger
4 provide a way to reduce the force necessary to initiate deployment (e.g., of fins, panels
24 or other devices) down to the order of a few pounds or even ounces of force.

2 Accordingly, in a preferred embodiment, the spring 10 has a spring force of about a
pound or just ounces, and thus the solenoid need only overcome a force of about a pound
4 or just ounces.

When circuit 12 is turned on, current flows to coil 6 inducing a magnetic field (as
6 is well known in the art of solenoids), to move the plunger 4 downward in Figure 1. The
magnetic force is preferably sufficiently strong to overcome the force of biasing member
8 (e.g., a spring) 10. Shaft 4b moves such that recess 4c moves adjacent to balls 8, which
roll or fall into the recess. The portions of balls 8 protruding beyond housing 2 no longer
10 protrude or protrude relatively little, so as to release the member 20 from the locking
device allowing it to move downward by gravity, and/or biasing device 24. Device 24
12 acts on member 20 pulling (or pushing) it in the downward direction in Figure 1.

Alternatively, biasing device 24 acts on a member 22 pulling (or pushing) it in the
14 upward direction in Figure 1.

Device 24 may be located above or below the member 20 or 22, as desired. The
16 biasing device's actual location, depends on the type of device, e.g., tension spring,
compression spring, other spring, resilient member, or otherwise, and depends on the
18 position of the member 20 (or 22) that is locked, and will be evident to one of ordinary
skill in the art. While two locking balls are shown, any number from one or more may be
20 used.

Figure 2 shows the position of the locking device in the released position and with
22 the biasing device omitted for simplification. Release occurs by sending electrical
current through the coils to induce a magnetic field acting on the plunger in a direction
24 (e.g., downward in Figures 1 and 2) opposite to the direction that the spring biases the

2 plunger (e.g., upward in Figures 1 and 2). The magnetic force is sufficient to overcome
the spring force (e.g., greater than about a pound or just ounces) to move the plunger
4 down sufficiently so that the recess aligns with the apertures. The balls will then enter
the recess and no longer retain the member 20 (or 22) that was locked. The greater the
6 solenoid's force, the faster the spring force will be overcome. Accordingly, the solenoid
must be designed taking into account the spring force, and the desired speed of release of
8 the locked member.

Button 4f (Figure 1) may provide for manually pressing plunger 4 down to
10 manually release the balls 8 and test the locking device. Button 4f preferably projects
above outer surface 26 of housing 2 when the plunger is in the locked position.

12 Figure 3 shows a portion of plunger 4 having the recess 4c, but each locking ball
is replaced with a lever 30. Lever 30 is rotatable on a pivot pin 30a, and may be
14 rotationally biased by a torsion spring (not shown), e.g., in a clockwise direction in this
embodiment. The lever has a locking arm 30b for holding a locked member 120 in place.
16 Locked member 120 may be positioned the same as member 20 or member 22 of Figures
1 and 2, as desired. The lever 30 also has a release arm 30c for rotating into recess 4c
18 when solenoid coil 6 (Figures 1 and 2) is activated by power on circuit 12 to move
plunger 4 down sufficiently so that recess 4c aligns with arm 30c, allowing arm 30c to
20 rotate (clockwise in Figure 4) into the recess.

Because the lever rotates, the locked member 120 is locked against upward
22 motion in this embodiment as shown in Figures 3 and 4. If the lever were oriented so that
arm 30c points down in Figure 3, and the lever were of a type that rotates
24 counterclockwise, the locked member 22 (Figures 1 and 2) may be locked against

2 downward movement. The location of pivot pin 30a would be moved upward, and the
plunger and solenoid would ideally be positioned so that the recess 4c is below apertures
4 2b₁ in the locked position, and so that the plunger is biased downward by a spring. The
solenoid when activated moves the plunger upward so that the recesses 4c will align with
6 apertures 2b₁ in lower housing 2a₁. In this way when the plunger is reset, its upper
beveled edge will push on arm 30c rotating the lever clockwise to position it in the
8 locking position.

In Figures 3 and 4 as shown, the plunger must move down to align the recess and
10 apertures. When the device is set or reset to the locked position, the plunger must be
moved upward so that lower beveled surface 4d rotates arm 30c counterclockwise against
12 the torsion spring bias to put the lever back into the locking position.

In another embodiment, a staggered release may be achieved, as shown in Figures
14 5 to 7. In Figure 5, a housing 102 holds a plunger 104 biased upward by a spring 110.
Two solenoid coils 106, 107 may be successively activated by power on source 112.
16 When the first solenoid coil 106 is activated, plunger 104 moves partway down such that
a first recess 104c in the plunger aligns with a first set of balls 108, partially releasing
18 locked member 120. Biasing member 124 pushes (or pulls) locked member 120
downward until it is stopped by a second set of balls 108a, as shown in Figure 6.

20 When second solenoid coil 107 is activated, plunger 104 moves down to the
position shown in Figure 7, where the second recess 105c is aligned with a second set of
22 apertures 103b, such that second set of balls 108a move radially inward and this fully
releases locked member 120.

24 Figures 8 and 9 show a variation of the previous embodiment, where two sets of

balls 208, 208a are released substantially simultaneously due to the plunger having one elongated recess 204c. Recess 204c is sufficiently long so that both sets of balls can enter recess 204c. There still may be a slight staggering effect to the release of the first and second sets of balls and therefore a slight staggering to the release of locked member 220 under the influence of biasing member 224, although depending on the speed with which the solenoid pushes the plunger down, this slight staggering may or may not be significant, as desired by the designer.

Figures 10 and 11 show a bomb or missile or torpedo (or an airborne device) with fins retracted before the solenoid is activated and thus locked in that position (Figure 10) and fins deployed after the solenoid is actuated and thus unlocked (Figure 11). Such device has a housing 400 and incorporates a solenoid release device 402 such as disclosed in the other embodiments herein. There is a mechanical linkage 404 to the locked member, e.g., member 22 in Figure 1. A star-shaped member 408 has grooved ends 408a which in turn prevent member 409 from moving, e.g., about a pivot point due to e.g., a torsion spring 410. When the solenoid is actuated, star member 408 is pulled upward through linkage 404 or otherwise moved out of engagement with member 409 at its end 409a, and spring 410 rotates end 409b out of engagement with fin 414, which is then deployed due to a bias outward and around a pivot point 416 connected to the fin at flange 418. In this manner, all four fins are deployed at the same time.

Figures 12 and 13 show an enlarged partial cutaway partial sectional view of another embodiment of the locking device in the locked position and released position, respectively. In this embodiment, as in others, like elements are given like reference numerals. This embodiment is similar to that of Figures 1 and 2, except that locked

2 member 320 is locked against upward motion under the bias of spring 324, and stopper
element 321 is shown to limit the downward motion of member 320 when being reset to
4 the locked position.

Also in Figures 12 and 13, one locking ball 8 is shown in phantom to indicate that
6 one or two balls 8 may be used, two being preferred for balance.

By way of example, a recess formed in locked member 320 may be about or less
8 than one half inch, e.g., about three tenths of an inch, in diameter and the diameter of the
bottom of the housing may be about one quarter of an inch. The force of spring 10, and
10 thus the solenoid specifications, may be readily determined knowing the biasing force of
biasing device 324, and setting the specifications (e.g., materials and dimensions) of the
12 locking balls, plunger, and recesses to hold the locked member 320 against the force of
biasing device 324. In a preferred embodiment, as noted above, the force of spring 10
14 may be, e.g., on the order of ounces and thus the solenoid need only counteract this very
small force in relation to the large force of the biasing member 324.

16 Fin deployment may be tested by actuating the solenoid. The fins may be reset,
usually done manually with the aid of a tool or tools to overcome the biasing forces on
18 the fins and other portions of the linkage. For example, once the member 20 in Figs. 1
and 2 is moved back to the position of Fig. 1, the force of biasing member 10 causes the
20 plunger to move up and the balls 8 to move outward to the locking position, completing
resetting of the device. The device is then ready for repeated use.

22 Although the invention has been described using specific terms, devices, and/or
methods, such description is for illustrative purposes of the preferred embodiment(s)
24 only. Changes may be made to the preferred embodiment(s) by those of ordinary skill in

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- 2 the art without departing from the scope of the present invention, which is set forth in the following claims. In addition, it should be understood that aspects of the preferred
- 4 embodiment(s) generally may be interchanged in whole or in part.